Endovascular, transperitoneal, and retroperitoneal abdominal aortic aneurysm repair: Results and costs

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Purpose: **Contemporary treatment of abdominal aortic aneurysms (AAA) includes transabdominal (TA), retroperitoneal (RP), and endovascular (EV) repair. This study compares the cost and early (30-day) results of a consecutive series of AAA repair by means of these three methods in a single institution.**

Methods: **A total of 125 consecutive AAA repairs between February 1993 and August 1997 were reviewed. Risk factors, 30-day morbidity and mortality rates, and hospital stay and cost were analyzed according to method of repair (TA, RP, EV). Cost was normalized by means of a conversion factor to maintain confidentiality. Cost analysis includes conversion to TA repair (intent to treat) in the EV group.**

Results: **One hundred twenty-five AAA repairs were performed with the TA (n = 40), RP (n = 24), or EV (n = 61) approach. Risk factors among the groups (age, coronary artery disease, hypertension, diabetes, chronic obstructive pulmonary disease, and cigarette smoking) were not statistically different, and thus the groups were comparable.**

The average estimated blood loss was significantly lower for EV (300 mL) than for RP (700 mL) and TA (786 mL; $P > .05$). Statistically significant higher cost for TA and RP for pharmacy and clinical laboratories (likely related to increased length of stay [LOS]) and significantly higher cost for EV in supplies and radiology (significantly reducing cost savings in LOS) were revealed by means of an itemized cost analysis. Operating room cost was similar for EV, TA, and RP. There were six perigraft leaks (9.6%) and six conversions to TA (9.6%) in the EV group.

Conclusion: **There were no statistically significant differences in mortality rates among TA, RP, and EV. Respiratory failure was significantly more common after TA repair, compared with RP or EV, whereas wound complications were more common after RP. Overall cost was significantly higher for TA repair, with no significant difference in cost between EV and RP. EV repair significantly shortened hospital stay and intensive care unit (ICU) use and had a lower morbidity rate. Cost savings in LOS were significantly reduced in the EV group by the increased cost of supplies and radiology, accounting for a similar cost between EV and RP. Considering the increased resource use preoperatively and during follow-up for EV patients, the difference in cost between TA and EV may be insignificant. EV repair is unlikely to save money for the health care system; its use is likely to be driven by patient and physician preference, in view of a significant decrease in the morbidity rate and length of hospital stay. (J Vasc Surg 1999;30:59-67.)**

Endovascular repair of infrarenal abdominal aortic aneurysms (AAAs) is an attractive approach in the treatment of patients with infrarenal AAAs. The evaluation, to date, of the early and midterm results suggest a significant decrease in hospital stay and periprocedural morbidity when compared with open surgical repair.[1,2] Initial results with this approach have been promising, and the follow-up to date suggests that it will become an integral part of the armamentarium in the treatment of patients with aneurysmal disease.

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	Mortality	*Morbidity*				
	$P > .3$	*Respiratory failure*	*Wound*	*Other**	*Hospital stay/ ICU (days)*	*Cost factor*
TA (n = 40)	2.5% (1)	12.5% (5) ($P < .05$)	2.5% (1)	15% (6)	9.6/3.1	1469.8 ($P < .05$)
RP (n = 24)	4.2% (1)	4.2% (1)	12.5% (3) ($P < .05$)	12.5% (3)	8.1/3.1	1176.3†
EV (n = 61)	0	0	0	13.1% (8)	4/0.5 $P < .0001$	1000‡
Overall (n = 125)	1.6% (2)	4.8%	3.2%	13.6%	7.2/2.2	

*Pneumonia, bleeding, myocardial infarction, renal failure, graft thrombosis (no statistical significance).
†RP vs. TA, $P < .05$.
‡EV vs. TA, $P < .0003$; EV vs. RP, $P > .1$.

Retroperitoneal repair of infrarenal AAAs has been preferred by some physicians because of a perceived decrease in pulmonary complications and faster return of gastrointestinal function.[3-4] When retroperitoneal repair is evaluated in a prospective randomized fashion, compared with the transperitoneal approach, no advantage has been found by some investigators,[5] whereas others reported fewer complications, shorter hospital stays, and lower costs for the retroperitoneal approach.[6] Nevertheless, the retroperitoneal approach to infrarenal AAA repair has slowly gained popularity and has become part of the current acceptable approaches to aortic aneurysms.

Transperitoneal AAA repair is the standard method used by most vascular surgeons in the treatment of patients with infrarenal AAAs. Vascular surgeons are familiar with this technique, which has been proven both safe and durable, with mortality rates of approximately 2% to 4% and acceptable morbidity rates less than 20%.[7-9] In fact, the transperitoneal approach serves as the "gold standard" to which other methods must be compared.

The availability of the endovascular approach at the UCLA Medical Center has given us the unique opportunity to evaluate the contemporary management of infrarenal AAAs, comparing the endovascular, retroperitoneal, and transperitoneal approaches in a consecutive series of patients seen between February 1993 and August 1997. This study compares the cost and early (30-day) results in a consecutive series of AAAs that were repaired by means of one of these three methods in a single institution.

MATERIALS AND METHODS

All patients evaluated for endovascular repair of infrarenal AAAs at the UCLA Medical Center between February 1993 and August 1997 were included in this review. Excluded from consideration were patients who required additional procedures at the time of aneurysm repair, such as visceral (renal, mesenteric) bypass grafting procedures, peripheral bypass grafting procedures, juxtarenal aneurysms requiring suprarenal aortic clamping, or combined operations (ie, cholecystectomy or carotid endarterectomy). In addition, patients who did not meet physiologic inclusion criteria for endovascular repair (Food and Drug Administration protocol, American Anesthesia Association class I to IV, life expectancy longer than 2 years), or had exclusion criteria (ruptured aneurysm, active infection, weight of more than 350 pounds, transplant patients, bleeding diathesis, or aneurysm etiology other than atherosclerosis) were also excluded from consideration. Thus, only patients who were acceptable candidates for surgical intervention were considered for endovascular repair. The patients were divided into three groups, according to the method of repair: transabdominal (TA), retroperitoneal (RP), or endovascular (EV). Risk factors, 30-day morbidity and mortality rates, length of hospital stay, and costs were analyzed according to the method of repair.

Medical records were retrospectively reviewed, and risk factors were noted (age, coronary artery disease, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, and history of cigarette smoking). Each group was compared for preoperative risk factors to determine any statistical difference. Morphologic features of the aneurysm that excluded the patient as a candidate for EV repair, and thus proceeding with conventional (TA, RP) surgical intervention, were noted.

During the study period, all patients were considered for EV repair of their infrarenal AAA. Patients who were not deemed candidates for EV repair because of morphologic reasons were then considered for surgical intervention. The most common anatomic reason for exclusion in the EV group was the absence of a proximal neck, with presence of significant iliac aneurysmal disease, occlusive disease, or both preventing adequate EV access being the second and third most frequent causes for exclusion.

Operative factors were also analyzed. These included total operating time, total blood loss, and any intraoperative complications requiring a change in operative plan. This included conversions to surgical repair in the EV group or additional procedures required in the surgical group.

Postoperative morbidity occurring within the first 30 days or before hospital discharge were noted. These included pneumonia, postoperative bleeding, myocardial infarction, renal failure, graft thrombosis, respiratory failure, and wound complications. Mortality was defined as death occurring within 30 days of the procedure or during the same hospital admission.

The length of hospital stay was analyzed and included any preoperative days that were necessary as part of the workup for the AAA. Days in the intensive care unit were analyzed separately and were included in the hospital stay.

Total cost of the procedure and hospital stay were analyzed. This included the costs of the entire hospital stay and procedure, which were further analyzed specifically as to operating room costs, supplies, pharmacy, radiology, respiratory service, and clinical laboratories. The cost of the EV device was included in supplies. Cost figures were normalized with a conversion factor to maintain institutional confidentiality. The conversion factor was determined to be a denominator that would yield a cost factor of 1000 in the group with the lowest total cost. All other cost factors were determined by this denominator. Hospital charges or reimbursement were not considered. Patients who were initially treated with the EV approach but converted to a transperitoneal approach were included in the total cost of the EV group. Total cost for all groups includes the entire hospitalization, including costs related to complications.

Surgical technique in the TA group included either a midline or a bilateral subcostal incision. All RP exposures were carried out by making a curvilinear incision, starting at the tip of the 11th rib, and continuing obliquely to a point midway between the pubis and the umbilicus. Graft configurations were either tube or bifurcated, depending on the presence or absence of aneurysmal disease at the iliac arteries. All grafts were made of Dacron.

All patients in the EV group were examined preoperatively with imaging modalities to determine precise aneurysm and aortic measurements. A preoperative arteriogram was routine in the examination of EV patients and was selectively used in the surgical groups. All preoperative evaluation was excluded from cost consideration to avoid the bias that would otherwise occur, because EV group patients were all part of a strict Food and Drug Administration protocol. Most patients were referred to our institution, with studies done at other facilities. Cost information of these studies was not available. Furthermore, if these initial studies suggested appropriate anatomy for EV repair, they frequently were repeated for more detail (computed tomography with 3 mm slices). Magnetic resonance imaging and magnetic resonance angiography were performed most frequently in the EV group. Thus, to avoid bias against the EV group, all preoperative evaluations were excluded from cost considerations.

The EV procedure was carried through a transfemoral approach, either unilateral or bilateral, depending on the graft configuration (tube versus bifurcated versus aortoiliac with femorofemoral bypass graft). The grafts were manufactured by EndoVascular Technologies (Menlo Park, Calif) and consisted of a Dacron material with attachment systems proximally and distally.

RESULTS

A total of 125 patients with AAAs underwent either open or EV repairs at the UCLA Medical Center between February 1993 and August 1997. The TA approach was used in 40 patients, the RP approach in 24, and the EV approach in 61. Risk factors among the three groups are presented in Table I. There was a statistically significant higher number of patients with hyperlipidemia in the RP group. Otherwise, there was no statistically significant difference in preoperative risk factors among the groups, and thus, the groups were comparable. Anatomic differences between the EV and surgical group dictated method of repair. Otherwise, the groups were comparable.

The 30-day mortality rate was 2.5% (1 of 40) in the TA group, 4.2% (1 of 24) in the RP group, and no mortality occurred in the EV group (0 of 61). There was no statistically significant difference in mortality rates among the three groups ($P > .3$).

The death in the transabdominal group was caused by a myocardial infarction in a patient with respiratory failure. The mortality in the retroperitoneal group was caused by multisystem organ fail-

Table I. Preoperative risk factors in patients with abdominal aortic aneurysm

	Endovascular	*Retroperitoneal*	*Transabdominal*
Number of patients	61	24	40
Hypertension	55% (30)	58% (14)	58% (23)
Coronary artery disease	38% (21)	38% (9)	43% (17)
Smoking history	53% (29)	46% (11)	53% (21)
COPD	22% (12)	25% (6)	23% (9)
Diabetes mellitus	9% (5)	13% (3)	8% (4)
Peripheral vascular disease	9% (5)	13% (3)	20% (8)
Earlier stroke	11% (6)	4% (1)	20% (8)
Hyperlipidemia	9% (5)	21% (5)	8% (3)

$P < .001$; *COPD,* chronic obstructive pulmonary disease.

Table II. Postoperative morbidity in 125 patients with abdominal aortic aneurysm

Complication	*Endovascular (n = 61)*	*Retroperitoneal (n = 24)*	*Transabdominal (n = 40)*	*P value*
Blood loss	300 mL	700 mL	786 mL	< .05
Arrhythmias	0	12.5% (3)	10% (4)	< .05
Pneumonia	0	0	2.5% (1)	NS
Respiratory failure	0	4.2% (1)	12.5% (5)	< .05
Postoperative bleeding	0	0	2.5% (1)	NS
Wound	0	12.5% (3)	2.5% (1)	< .05
Myocardial infarction	0	4.2% (1)	2.5% (1)	NS
Renal failure	0	4.2% (1)	2.5% (1)	NS
Graft limb thrombosis or stenosis	3.6% (2)	0	5% (2)	NS
Endoleak	9.8% (6)	NA	NA	

ure after a peripheral embolization during aneurysm repair. This patient had had a stroke 2 months before surgery during a coronary catheterization. He had an expanding AAA.

The 30-day morbidity rate is summarized in Table II. There was no statistically significant difference in the incidence of pneumonia, perioperative bleeding, myocardial infarction, renal failure, or graft thrombosis among the three groups. There were no instances of major peripheral embolization in the EV group. A statistically significant increased incidence of respiratory failure was noted in the TA group. Respiratory failure requiring reintubation with prolonged respiratory support developed in five of the 40 patients operated on via the TA approach, versus one patient in the RP group, and no patients in the EV group ($P < .05$). Wound complications were more frequent in the RP group, with three patients in whom either wound dehiscence (one patient) or superficial wound infection requiring partial opening of the incision (two patients) developed, compared with one patient in the TA approach and no patients in the EV group in whom a small wound collection developed (TA versus RP versus EV, $P < .05$). The single wound dehiscence (partial) in the RP group occurred in a morbidly obese patient (weighing 340 lb), who had chronic obstructive pulmonary disease and was successfully treated conservatively. A significantly higher incidence of arrhythmias was seen in the TA and RP group compared with the EV group. All other complications occurred with a similar incidence among the three groups.

As mentioned before, anatomic differences dictated EV or open surgical repair. Of the 61 EV cases, 30 were tube grafts, 20 were bifurcated prosthesis, and there were seven patients treated with an aortouniiliac and femorofemoral bypass grafting procedure. In the TA group, there were 16 aortoaortic (tube) graft repairs and 24 bifurcated prosthetic graft implantations. Of the 24 retroperitoneal repairs, there were 10 tube and 14 bifurcated grafts. Thus, aortoaortic repairs were most common in the EV group, likely reflecting the initial availability of that particular prosthesis.

The operating time was similar for the three groups. Mean operating room times were 283 ± 92 minutes for the EV group, 296 ± 115 for the RP group, and 298 ± 122 for the TA group. The mean operating time in the EV group was similar for the tube (231 minutes) and the bifurcated (246 minutes) configurations. However, tube graft repairs

Table III. Cost analysis of 125 patients with abdominal aortic aneurysm

Item	*Endovascular (n = 61)*	*Retroperitoneal (n = 24)*	*Transabdominal (n = 40)*	*P value*
Operating room	289.4	289.8	323.6	NS
Supplies	348.6	240.6	264.1	< .05
Respiratory service	21.6	110.8	162.1	< .05
Pharmacy	143.7	326.9	377.1	< .05
Radiology	203	63	57.9	< .05
Clinical laboratories	58.4	131.9	214.6	< .05
Total*	1000 ± 480.1†	1176 ± 466.3‡	1469 ± 689.8	(See footnote)

*Cost factor ± SD
†Endovascular vs. transabdominal, $P < .0003$; endovascular vs. retroperitoneal, $P > .1$
‡Retroperitoneal vs. transabdominal, $P < .05$

were most common early in the EV experience. The mean operative time for aortouniiliac and femorofemoral repair was significantly longer (372 minutes) than EV tube or bifurcated repairs. The mean estimated blood loss for the TA group was 786 mL (range, 150 to 3000 mL). The RP group had a mean blood loss of 700 mL (range, 200 to 3000 mL). The difference between these two groups was not significant. The EV group had a significantly lower estimated blood loss, with a mean of 300 mL (range, 100 to 1300 mL; $P < .05$).

The total length of hospital stay was significantly lower in the EV group, which had a mean hospital stay (± SD) of 4 ± 2.5 days, compared with 9.6 ± 4.0 days for the TA group and 8.1 ± 3.1 for the retroperitoneal group ($P < .0001$). A similar significant decrease in ICU length of stay was noted, with the EV group having a mean ICU day stay of 0.5 ± 1.3 days, compared with 3.1 ± 2.1 days for the TA group and 3.1 ± 1.6 days for the RP group ($P < .0001$).

Overall results for the entire experience, combining the three groups, yields a mortality rate of 1.6% (2 of 125 patients) and an overall morbidity rate of 21.6%, which included all postoperative complications. The overall mean length of hospital stay for the entire series was 7.2 days, with an ICU stay of 2.2 days.

In the EV group, there were six perigraft leaks persistent at 30 days (9.6%). There were also six conversions to surgical repair in the EV group (9.6%). All conversions were done at the time of attempted EV repair. Three conversions were necessary because of difficulty with access caused by small or tortuous iliac vessels, two were necessary because of significant endoleaks at the distal attachment site of a tube graft repair, and one was necessary because of subintimal placement of the proximal attachment system early in the experience. All patients in the EV group undergoing conversion to surgical repair recovered without complications and are included within the EV group as an intent-to-treat analysis.

The overall cost factor for the EV group was 1000. This was statistically lower than the cost factor for the TA group, which was 1469.8 ($P < .05$). The cost factor for the RP group was 1176.3, which is not significantly different statistically from the cost factor for the EV group. A statistically significant higher cost for pharmacy and clinical laboratories for the TA and RP groups was revealed by means of further itemized cost analysis; this was likely related to the increased length of stay. A significantly higher cost factor in supplies and radiology, which significantly reduced the cost savings obtained because of a decrease in length of stay, was seen in the EV group. Operating room costs were similar for the EV, the TA, and the RP groups. There were no differences in the cost factor between tube and bifurcated repair within the EV, TA, or RP groups. However, within the EV group, aortouniiliac/femorofemoral repairs had a significantly higher cost factor (1604), compared with the overall cost factor for the entire group. One of the seven patients within the aortouniiliac/femorofemoral group had a prolonged hospital stay (15 days) because of complications; however, even when this prolonged stay was eliminated from the cost analysis, the cost factor for the remaining six patients in this group was significantly higher (1328). This was probably caused by an increase in operating time, because the length of hospital stay was similar (mean, 3.6 days) to the overall EV group. Cost factor analysis is presented in Table III.

DISCUSSION

Contemporary management of infrarenal AAA is likely to be expanded to include EV repair. Recent initial reports of the EV experience with infrarenal AAAs have suggested a decrease in morbidity rate and length of hospital stay. Although mortality rates have not been significantly different, some series have included patients with greater comorbidities, which some investigators suggest may have eliminated any potential difference in mortality rates. Nevertheless, it has been proposed that, because of the significant decrease in length of stay, significant cost savings should be realized.

Our experience to date suggests that patients undergoing EV aneurysm repair do indeed have a significantly shorter hospital stay. This is likely related to the rapid recovery that is seen after EV repair and a significant decrease in the morbidity rate that is specifically related to respiratory failure. The mortality rate in our series was not significantly different among the TA, RP, and EV approaches. However, the failure to demonstrate a difference in a relatively small series must be interpreted with caution. Nevertheless, series reported to date concur with our findings; mortality does not seem to be significantly different between the EV and the surgical approaches.[1-2] This underscores the excellent results that can be accomplished with modern surgical techniques, even in patients with significant comorbidities.

The RP approach has been preferred by some physicians because of a perceived faster recovery time and less impact on pulmonary function. Randomized trials to date have had mixed results. In a study by Cambria et al,[5] no significant advantage was demonstrated for the RP approach. Sicard and colleagues,[6] on the other hand, showed not only a decrease in postoperative complications, but also a decrease in length of hospital stay and lower cost, when compared with the TA approach. In our experience, we saw a decrease of 1.5 days in total hospital stay in the RP group, which translated into a significant decrease in cost compared with the TA approach. No significant difference in cost was seen when comparing the RP approach with the EV approach. A significantly lower incidence of respiratory failure was seen in the RP group, compared with the TA group. However, a significantly increased incidence of wound complications was seen with the RP approach. This, however, did not prolong the length of hospital stay or lead to any serious sequelae.

Our overall results must be interpreted with caution. First, it is a relatively small series, which, when further subdivided into three groups, dilutes the statistical power of its conclusions and may not demonstrate differences, even though they may exist (Type II statistical error). In spite of this, significant differences were noted, particularly in the early cost of care between the TA group and EV group and the overall morbidity rates between the surgical group and the EV group. Second, although there were no significant differences in comorbidities among the groups, there were anatomic differences between the surgical group and the EV group. We attempted to decrease the impact of these differences by eliminating complex repairs beyond standard infrarenal repair with tube or bifurcated grafts from consideration. Nevertheless, because this was not a randomized prospective study, potential error in the comparison is inevitably introduced.

Third, although performance of the TA approach was distributed among our colleagues, the RP approach was performed mostly by one surgeon. Although this may introduce bias in the results, no differences were noted in the results of the TA group among our team, suggesting comparability in surgical skill. Fourth, the EV group represents the experience with one particular device (Endovascular Technologies/Guidant, Menlo Park, Calif), which may or may not be comparable with other devices under investigation.

Finally, this series only looks at the initial results and cost. Preoperative evaluation was not included. We believe that, because the minimum necessary studies for EV repair remains to be established, it would be unfair to include these at this time. The eventual long-term outcome and cost of care of patients in the EV group remains more important. This must await further analysis, which is currently in progress.

Considering the increased resource use that will be required, at least within the next 10 years, in patients treated with the EV approach, the potential cost savings related to the length of hospital stay may be eliminated. In fact, we could not demonstrate a significant difference between the cost of the EV approach and the RP approach, in spite of a 4-day difference in the length of hospital stay. Most of the savings were eliminated because of the cost of supplies, radiology equipment, and personnel necessary for EV grafting.

In conclusion, transperitoneal repair is associated with a higher incidence of respiratory failure and overall cost when compared with the RP approach or the EV approach. EV AAA repair significantly shortens hospital stay and ICU use and has a lower morbidity rate. Cost savings in the length of stay for the EV group are significantly reduced by the increased cost of supplies and radiology, which accounts for the similar cost between EV repair and RP repair. Considering the increased resource use during follow-up for patients undergoing EV aneurysm repair, the difference in cost between the

TA approach and the EV approach may be insignificant. EV AAA repair is unlikely to save money for the health care system; its use is likely to be driven by patient and physician preference, because of a significant decrease in morbidity rate and length of hospital stay.

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DISCUSSION

Dr Jerry Goldstone (San Francisco, Calif). The objective of this study was to compare the cost and early results of a consecutive series of abdominal aortic aneurysms repaired by three methods: transfemoral endovascular, transperitoneal open surgical, and retroperitoneal open surgical. A total of 125 consecutive patients were treated in a 54-month interval. By means of simple math, this represents 2.3 aneurysm repairs per month or 28 per year. Because the authors were the first physicians in this country to implant a Guident-EVT endograft and because that procedure was performed in February 1993, I assume that this report encompasses the entire UCLA experience with the endovascular treatment of abdominal aortic aneurysms. This leads me to my first set of questions. How many of the endografts were tubes? How many were bifurcated? And how many were aortouniiliac with femorofemoral bypass grafts? Were there any differences in any of the variables, such as procedure duration, blood loss, graft limb thrombosis or stenosis, or other complications, studied within these groups? The authors acknowledge that these patients were participants in a strictly monitored, Food and Drug Administration-approved protocol. Were there any compassionate-use patients in this study cohort, and, if so, how did their results compare with that of the others? And what about the learning curve? The UCLA group has now had a large experience, perhaps the largest, with these particular devices. Were there any differences in outcome measures between the first part of the series and the last part? One would anticipate that there would be differences.

How were the open surgical patients selected for either retroperitoneal or transabdominal approaches? Was there a protocol for this? If it was based on individual surgeon preference, could there have been patient-related factors that influenced the decision and thereby influenced the results? Were the retroperitoneal procedures performed by one or two surgeons experienced with this method, or was there also a learning curve here?

There was a statistically significant increased incidence of respiratory failure in the transabdominal group. How was respiratory failure defined for this study, and were there any unusual features in this group of patients that could have predisposed them to this postoperative complication? For example, some of the transabdominal group received a bilateral subcostal incision. This is, in my opinion, a very unusual incision for an infrarenal aortic aneurysm operation, in distinction from the supraumbilical transverse incision popularized by the group at the University of Michigan.

In contrast to respiratory complications, wound complications were more frequent in the retroperitoneal group. The authors didn't mention the occurrence of a flank bulge or hernia, which is a well-recognized and bothersome complication after this approach. Were there any such late wound problems?

Finally, about cost, one of the primary questions that this study sought to answer: Do the figures presented represent actual cost, or do they represent charges? We all know that these are not the same, although purely for comparison purposes either one might be valid. Two of the most significant costs for these treatments are the length of hospital stay and the operating room costs.

The 9.6-day average hospitalization for the transabdominal group seems high by today's standards. Many series now report hospital discharge between 5 and 7 days after uncomplicated abdominal aortic aneurysm repair. In spite of the reduction in length of stay to 8.1 days in the retroperitoneal group, this figure also seems excessively long. In the recently reported EVT phase II trial, the average length of stay in the open surgery group was 7.1 days. Were there any trends noted in the length of stay during this 4.5-year interval, and what accounts for the seemingly excessive hospitalizations? The length of stay averaged 4 days for the endovascular group; this period is essentially identical to the 3.7 days in the EVT trial. The average time for the procedures in this series ranged from 283 minutes for endoluminal repair to 298 minutes for retroperitoneal open repair. Again, these values appear to be long when compared with the EVT phase II data; endovascular repair averaged 168 and 212 minutes for the tube and bifurcated devices, respectively, and 174 minutes for open repair—differences of at least 1 hour in each group. These are expensive differences.

Another point worth mentioning is that the authors excluded the cost of the preoperative imaging studies in the endoluminal treatment group. Because these imaging studies are essential to the safe conduction of the procedure, I believe that their cost must be included in any economic analysis. Furthermore, because of the uncertainties about endoleaks, a certain number of postprocedure imaging studies are performed in these patients, and although they may be protocol driven, it is probable that at least some of them will be performed in the absence of protocol requirements. Therefore, I believe that these charges also must be included in the endovascular tally.

I have one last question about cost. What was the cost of the endograft device, was it included in the analysis, and if not, why not?

In summary, the UCLA group has demonstrated that they can treat abdominal aortic aneurysms in at least three ways with equally excellent results. However, I believe that they have underestimated the resource use required for endovascular repair, and, therefore, I question the conclusion that transabdominal repair is more expensive than endoluminal repair. This report does not define the future role of endovascular aortic aneurysm repair, but that was not its purpose. It does, however, add to the growing body of knowledge about this exciting treatment modality.

Dr William J. Quiñones-Baldrich. I would like to thank D. Goldstone for his comments and excellent questions. I will try to answer these questions in order.

There were 61 patients in the endovascular group. Thirty of these patients had tube endografts, there were 24 bifurcated endovascular grafts, and seven patients underwent aortouniiliac and femorofemoral reconstruction. Dr Goldstone raised the issue about the overall time in the operating room for these cases, which appears somewhat longer than what has been reported in the initial EVT report. The average time for endovascular repair was 283 minutes. When this is broken down into the tube, bifurcated, and aortouniiliac implants, the tube grafts had an average time of 231 minutes, versus 246 minutes for the bifurcated grafts, which is not a significant difference. However, aortouniiliac reconstructions with femorofemoral bypass grafts had a significantly longer operative time, 372 minutes, which helps explain why our overall average time is higher than has been previously reported. In addition, surgical time in our operating room starts as soon as the patient receives anesthesia; during general anesthesia, this is as soon as the endotracheal tube has been placed. Therefore, the time that it takes to place the Foley catheter, prepare the patient, etc, is included in the operative time. Other complications within these groups, however, were not significantly different. There was one patient who received a tube graft on a compassionate-use basis. This patient recovered well from his surgery; however, he died of respiratory failure 8 months later.

There is clearly a learning curve with the endovascular grafts. However, if we look at our own series, it is evident that easier cases were selected in the early part of the experience, whereas now we're tackling more difficult cases. So, although the learning curve is there, we are not seeing any significant impact on the early and late part of our experience. We have seen, however, a significant increase in operative time in the aortouniiliac-femorofemoral reconstruction. Therefore, I do not believe that the "learning curve" would affect our conclusions.

Patients in the surgical group were selected on the basis that they were not candidates for endovascular grafts. In deciding whether to proceed in a transabdominal or a retroperitoneal approach, there is no protocol at our institution for selection. This is based on the surgeon's preference. Most of the retroperitoneal cases were my own, because I favor that approach for the surgical repair of most infrarenal abdominal aortic aneurysms. Cases using the transabdominal approach was distributed among our group. As far as patient-related factors to account for any difference, there were certainly no differences in preoperative risk factors, with the exception of hyperlipidemia, which I do not believe would significantly affect early outcome. Certainly for the retroperitoneal approach, there is a learning curve; however, this learning curve did not occur during this study period, because I have been doing retroperitoneal abdominal aortic aneurysm surgery almost routinely since 1989.

Respiratory failure was defined as a patient requiring reintubation for more than 72 hours after initial extubation. Most patients with respiratory failure had a significant history of chronic obstructive pulmonary disease. Regarding the transverse abdominal incision: This is the preference of one of the surgeons in our group. As far as the bulging or hernia that can occur with the retroperitoneal approach, this certainly was something that I saw early on in my experience. However, for the last 6 years, it has been my practice to divide the internal oblique muscle along the rectus border, which seems to have eliminated this problem.

This report deals only with costs, not charges. These costs were obtained from the confidential computerized system that is used in a hospital to track these items. Thus, the figures all represent costs. Regarding trends in hospital stay: I do not have this information at hand; however, it is my impression that there has been a decrease in length of hospital stay, particularly for the transabdominal and retroperitoneal group. We have all been forced to reduce the length of these stays because of the current environment. However, the hospital stays reported include prolonged stays for complications. In addition, an earlier presentation noted that a low mortality rate actually can be reflected in a longer hospital stay, and vice versa. However, the hospital stay for the transabdominal approach was significantly longer than that for the retroperitoneal approach, about 1.5 days longer.

The cost of preoperative evaluation was not included in the calculation of costs, mainly because I felt this would establish a bias against the endovascular group. This particular group of patients is currently under protocol, and therefore there are several studies (particularly magnetic resonance angiography and magnetic resonance imaging) that would significantly increase the cost without really giving us actual information on the cost of the procedures and the hospital stay. In addition, the preoperative evaluation for surgical repair varies among our group. Some physicians are more liberal with angiography than others, and, again, this would introduce variables into the mix that would make interpretation of the data more difficult. Furthermore, many of these studies are done outside our facility, and, therefore, we have no cost information on them. Often patients who come to or are referred to our institution already have had a computed tomography scan.

One of the conclusions that we have proposed speculates on the very fact that you mentioned about the cost of postoperative studies in patients that have endoleaks. This certainly will be a significant factor. However, keep in mind that this particular study only looks at the first 30 days of care. Again, I felt that going beyond that not only would be difficult because of the uncertainty involved in the particular studies that are necessary to elucidate an endoleak, but also because the endovascular patients are part of a protocol.

The cost of the endograft is certainly an important factor in increasing the cost of the endovascular repair. I don't have an exact figure on the cost of the endograft; however, my information is that it is somewhere between \$5000 and \$6000.

Finally, I agree with you that the cost of the transabdominal approach may not be significantly higher than the endovascular approach, because of the cost of surveillance in these patients, and this is exactly the reason why we concluded that endovascular repair is unlikely to decrease the overall cost to the health care system. This is most evident because the initial cost for the first 30 days of care is not that much different, in spite of a significant difference between the surgical and endovascular groups for the length of hospital stay and morbidity rate.